MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

REPORT
for year 1950

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REPORT
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PREFACE

By the Chairman, Fred. C. Atkins, Esq.

The year 1950 was a difficult one for all engaged in horticulture, and the price of mushrooms fell to the lowest level for 10 years. It was not really surprising, then, that contributions to the Research Fund fell £500 short of our target.

A further approach had to be made to the Ministry of Agriculture, and with the support of the Agricultural Improvement Council and the Agricultural Research Council it was arranged that the 50% grant-in-aid be increased to 60% for 1950.

The Ministry generously went further. Realising how anxious the Mushroom Industry was to keep the Yaxley Station operating, the offer was made to contribute up to 75% of the running expenses provided the Industry guaranteed to find at least 25% for the next three years. Capital expenditure not qualifying for grant, this meant about £1,500 p.a. from the Industry in 1951, 1952 and 1953, and so far as we were able, the Executive Committee of the Mushroom Growers' Association accepted responsibility for the raising of this sum.

Pleasure equalled my pride in being elected Chairman of the M.R.A. for 1950, and it proved to be a significant year. Apart from the laying of this broader and more solid financial foundation, work on Synthetic Composts was curtailed while commercial-scale application was attempted, and preparations were made for an assault on the equally important problem of Casing Soil.

Work on disease control was still hindered by the need for a Disease Room, but plans are afoot to provide one in 1951. Maintenance and development continue to depend on the support of growers and others associated with the cultivation of mushrooms, and I trust the other 230 subscribers who enabled us to survive 1950 will allow me here to refer with gratitude to the generosity of Messrs. Francis Nicholls Ltd., who each year repeat their cheque for 100 guineas, and to Mr. John Beveridge who, learning of our autumn struggles, promptly increased his contribution to £50.

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GENERAL REPORT

The work of the Research Station has continued smoothly during 1950.

Completed cropping experiments dealt with racing stable manure, composting methods, and alternatives to dried blood, as a source of nitrogen. They are fully described in pages 8-13. Others on the use of barley straw, phosphate, trace elements, and casing were started and are still in progress.

The synthetic compost described in last year's Report has been on trial under normal commercial conditions by Messrs. Noble Mushrooms, Ltd. The results of the 5 crops grown have compared favourably with those obtained from horse manure under similar conditions.

A major change in programme which justifies some comment here was the introduction of casing soil as a subject for investigation. Only a survey of the problem and possibly preliminary laboratory work were planned for 1950, to be followed by a programme of laboratory and cropping experiments in future years. In so complex a subject quick results are not to be expected.

Although the precise function of casing soil on a mushroom bed is still unknown, observations on normal growing methods under various conditions and some recent investigations by Dr. Bels-Koning suggest that these factors are important :

The soil must be able to hold a certain amount of water, available to the mushroom, but not drying out too quickly.

It must allow air to pass through, to and from the compost.

It must have a suitable pH.

It need not supply any nutrients, and may be biologically inert, but some nutrients, growth substances, and other organisms may be able to increase crops.

The amount of water which must be held, and the porosity to air needed are closely related to the air conditions, temperature, relative humidity, and rate of ventilation. The porosity is in turn affected by the amount of water present in the soil, and by soil structure ranging from $\frac{1}{2}''$ lumps down to microscopic particles. The stability of this soil structure to watering is also important under dry conditions where frequent watering is necessary. This applies particularly at high temperatures when most watering is done and also respiration in the compost is highest, increasing the demand for air.

Clearly water-holding qualities and sustained porosity to air are dominant features of this hypothetical picture of the functions of casing soil, and accordingly these are the subjects chosen for investigation first. Other functions and essential properties of casing soil are not excluded, but a complex problem of this kind can only be studied by breaking it down into controllable parts and observing their behaviour separately.

In pursuit of this object laboratory experiments have started to study the proportion of water held by various soils, their rates of drying, and stability to watering. The methods are described in the report of the Chemistry Department, with a few preliminary observations, but this work is only just starting, and is expected to take several years. Cropping experiments will be arranged in conjunction with the laboratory examination of soils.

Chemical changes in the compost are still being studied. It was found that during wetting straw lost about 15% of its potassium by leaching, emphasising the need for care at this stage. During our practice of fermenting the bales after wetting, there was 1·5—21% (average 10%) loss of dry matter.

The loss of dry matter during composting is important in connection with economical use of manure or compost materials. It was greatest in those stacks where the highest temperatures were recorded and may also be related to the ratio of nitrogen to calcium in the compost.

The occurrence of calcium oxalate crystals on mushroom mycelium is well known, and some determinations of the oxalate content of mushroom compost were reported previously (Burrows, 1949). Oxalate is interesting because it is formed in quite large amounts, and might be related to exhaustion of the bed. However, we have now shown (pp. 17-19) that oxalate formation may start early in the life of the bed and may continue over a long period of time. The oxalate is sometimes used up during the later stages of the crop, either by the mushroom itself or possibly by other organisms in the bed.

In the Mycology Department the main subject has been Truffle. Experimental methods are still being improved to give more consistent results with this difficult fungus. Tests on a range of fungicides have shown that under certain conditions in the laboratory, a small amount of copper sulphate can act selectively, preventing growth of truffle without injuring the mushroom mycelium. This action appears to depend on suitable conditions in the compost and more work is needed (and is in progress) to find out how it can be usefully applied.

By courtesy of Noble Mushrooms Ltd. several possible disinfectants have been sprayed on beds attacked by " Bacterial Pit." In some instances the results looked encouraging, but they have been too variable for any useful application to commercial practice. These experiments will continue as opportunities occur.

The only change in staff in 1950 was the resignation of Mr. S. Burrows, who had been at Yaxley since the Research Station was founded. He was succeeded by Mr. P. B. Flegg.

A notable event was the first International Conference on Mushroom Science held in Peterborough during May, with Mr. Fred. C. Atkins as Chairman and Dr. R. L. Edwards as Honorary Secretary. About 40 members from eight countries took part in discussions and visits lasting a week. The Conference was arranged to follow the Open Day at Yaxley, arranged in conjunction with the Mushroom Growers' Association, when about 400 growers visited the Research Station.

Acknowledgments. Our thanks are again due to the Directors of the Association for advice based on their special knowledge and experience; to Messrs. Noble Mushrooms Ltd. for co-operation in experiments on " Bacterial Pit " and other services ; to Messrs. Geo. Monro Ltd. and Messrs. H. Mount & Sons Ltd. for gifts of the spawn used in experiments on Truffle ; and to members of other Research Institutions and the N.A.A.S. for information and advice.

CROPPING EXPERIMENTS — R. L. Edwards

Experiment 12. Fortifying Racing Stable Manure

Six tons of racing stable manure from Newmarket was stacked in twenty small bays in the composting shed and watered by drip pipes for twenty-four hours. These small stacks were then left to heat and to let the water become evenly distributed. After seven days they were turned and the Activators were added (Table 1). The cost was approximately 2d. per sq. ft. of bed for the nitrochalk and 6½d. per sq. ft. for the complete M.R.A. Activators. These costs would be covered by increased yields of about 1 oz. and 3 oz. per sq. ft. respectively. The stacks were turned again after one and two weeks and filled after the third week. Gypsum was added a week before filling to all stacks not receiving M.R.A. Activator ' C '.

The stack temperatures, time from spawning to first picking, duration of picking and yields are shown in Table 2.

Table 1

Racing stable manure approximately 6 cwt., no activator
R.S.M. 6 cwt.+Nitrochalk 21 lb.
R.S.M. 6 cwt.+M.R.A. activator 34 lb. 'A' (equiv. 1½ cwt. dry straw).
R.S.M. 6 cwt.+M.R.A. activator 34 lb. 'A'+' B ' ,, ,, ,, ,,
R.S.M. 6 cwt.+M.R.A. activator 34 lb. 'A'+'B'+6 lb.'C' ,, ,,

Table 2. Effect of supplements added to manure

	None	Nitro chalk	M.R.A.'A' Blood etc.	'A'+'B' Blood etc. + trace elements	Complete M.R.A. Activators
Stack temperatures	64	64	66	66	66 ± 1·5 °C.
First picking	70	73	73	73	74 days from spawning
Duration of picking	119	115	117	122	122 ± 5 days
Mushrooms/sq. ft.					
4 weeks	25	24	18	19	17
8 weeks	37	37	33	33	32
12 weeks	47	48	46	46	46
final....	50	51	51	52	52
Yield—					
4 weeks	1·2	1·3	1·1	1·1	1·1 lb./sq. ft.
8 weeks	1·8	1·9	1·8	1·9	1·9
12 weeks	2·2	2·3	2·3	2·4	2·4 ± 0·2
final	2·4	2·6	2·5	2·7	2·7
Average size final	0·78	0·80	0·78	0·83	0·83 oz./ mushroom

As a study of the effect of supplements to light manure, the experiment was unsatisfactory, because the manure was too rich ; it contained 1·55% of nitrogen on the dry matter on arrival and 2·16% at filling. The composts containing various nitrogenous supplements contained 2·55 to 2·77% at filling. Anything over 2% at filling is quite good and we should not expect a great increase in yield from further additions of nitrogen. At the same time, nitrogen may be regarded as a fair indicator of the quantity of droppings and urine in manure, which supply the other essential nutrients.

The untreated manure gave quite a good yield of 2·4 lb. per sq. ft. Some of the supplemented composts gave a little more, particularly at the end of the cropping period when the plain manure was the first to show signs of exhaustion.

The best average yield on a group of beds was 2·9 lb./sq. ft. from the nitrochalk supplement, and the best on a single bed 3·5 lb./sq. ft. from the complete M.R.A. supplement.

A batch of standard M.R.A. compost was made at the same time as these, and gave an average yield of 1·9 lb./sq. ft. ; the beds contained 14·5 lb. of compost per sq. ft. compared with 16·1 (average) of the horse manure composts.

Conclusions

The manure used for this experiment was too rich in droppings to need supplements. The slight increases in yield obtained with them were not statistically significant, although they were large enough to pay for the supplements.

M.R.A. synthetic compost gave a lower yield per square foot ; less compost was used, and the yield per ton of dry compost material was the same as from the horse manure.

Experiment 13

This was arranged in an attempt to study the effect of varying the composting period and of peak-heating. All stacks were made with the standard M.R.A. Activators. There were four treatments :—

6 stacks composted 4 weeks, turned weekly, filled, peak-heated.
6 stacks composted 3 weeks, turned after 2 weeks, filled, peak-heated.
6 stacks composted 4 weeks, turned weekly, filled, not peak-heated.
6 stacks composted 3 weeks, turned after 2 weeks, filled, not peak-heated.

Stacks were started at intervals arranged so that those to be peak-heated were ready for filling together and when this had been done the house was peak-heated ; the other stacks were ready for filling three days later and were transferred to the house on cooling after the peak-heat.

All beds were spawned on the day after this second filling. The results of the composting treatments are shown in Table 3.

There was no significant difference between the two composting periods, but unheated beds gave a slightly higher yield than the heated ones. There was no inter-action between composting time and peak-heating.

Table 3. Results of Experiment 13

	Heated	Unheated	Composted 3 weeks	Composted 4 weeks	
1st picking	59·4	57·8	59·8	57·8	±0·8 days from spawning
No. of mushrooms					
4 weeks	10·8	13·8	9·9	14·7	per sq. ft.
8 weeks	16·9	21·4	17·3	21·0	per sq. ft.
12 weeks	19·8	23·5	20·4	22·8	±2·5 per sq. ft.
Weight					
4 weeks	10·1	13·3	10·1	13·3	oz./sq. ft.
8 weeks	14·9	18·9	15·8	17·5	±1·4 oz./sq. ft.
12 weeks	17·1	20·0	17·8	19·4	±1·3 oz./sq. ft.
Average size					
12 weeks	0·86	0·86	0·87	0·85	

The best yield from a group of beds treated alike was 1·6 lb./sq. ft. from 4 weeks compost unheated.

Table 4. Effect of peak-heating composts in different shelves in house

	Yield, oz./sq. ft.	
	Peak-heated	Unheated
Top shelf	16·8	18·1
Middle	18·8	22·0
Bottom	15·8	20·1

Dry matter losses are given in Table 16 on page 21. They show that there is the difference to be expected due to fermentation during an additional week in the stack, but the dry matter loss during peak-heating was the same in both groups of composts. The experiment suggests that the number of turns can be reduced, at least under our conditions of composting with stacks never wider than five feet. This is the second experiment in which peak heating has not given any increase in yield, the earlier one with horse manure compost in trays was described in the M.R.A. Report for 1946-8.

The difference between peak-heated and unheated compost was greatest on the bottom shelves and least on the top ones (Table 4). There was a considerable difference in the bed temperatures reached on the three shelves ; the house was filled early in February and the bottom shelves did not reach 45° C. (113° F.) whereas the top ones reached 50° C. (122° F).

It is widely believed that fermentation at temperatures between 35° and 50° C. (95° and 122° F.) may be more harmful than no heating at all; this might explain the low yields from heated compost on the bottom shelves. Also the yield from bottom beds peak-heated was lower than that from the corresponding top beds, whereas with unheated compost the bottom beds gave the higher yield. Although this is not conclusive, it does rather suggest that the moderate heating which the bottom beds received tended to reduce the yield. However, the connection is uncertain because different stacks of compost were used on the three shelves, and therefore they are not strictly comparable.

Immediately after spawning, one-third of the beds were sprayed with 0·2% and one-third with 1% beef extract (Lab Lemco). The results in Table 5 show that this had no effect, whereas in a previous experiment similar treatment produced a considerable increase in yield. It is to be expected that the effect of any supplement containing growth substances will depend on the state of the compost and conditions of application. This experiment shows that sometimes there may be no effect at all.

Table 5. Effect of spraying with beef extract

	Untreated	Beef extract 0·2%	Beef extract 1%	
First picking	58·7	58·1	59·0	±0·7 day
No. of mushrooms				
4 weeks	12·5	12·9	11·5	per sq. ft.
8 weeks	19·2	19·4	18·9	per sq. ft.
12 weeks	21·3	22·1	21·5	± 1·2 per sq. ft.
Weight				
4 weeks	11·8	11·5	11·8	oz./sq. ft.
8 weeks	16·7	16·7	17·4	oz./sq. ft.
12 weeks	18·4	18·6	18·7	± 0·5 oz./sq. ft.
Average size				
12 weeks	0·86	0·84	0·87	

Conclusions

The yield from M.R.A. Synthetic compost made in three weeks, with one intermediate turn after two weeks, was not signficantly lower than that from stacks made in four weeks with weekly turns.

The yield from unheated stacks was slightly greater than that from similar stacks which were peak-heated.

Spraying with beef extract (0·2% and 1% at 1 pint on 10 sq. ft.) had no effect on the yield.

Experiment 14

In this experiment five different materials were used as sources of nitrogen, and also a mixture of two of them. Twenty-four stacks of compost were made in four blocks of six. Table 6 gives the quantities of test materials. Gypsum, potassium chloride, calcium carbonate, and trace elements were included at stacking, and superphosphate and gypsum at the fourth turn. Samples of the composts taken at filling were analysed. The moisture contents were uniform, between 73 and 76%. The hide and leather meal compost was rather acid and its ash content was low, evidence of smaller breakdown during composting than occurred in the other stacks. This has been observed before.

Results are given in Table 7 except for the compost containing cyanamide which was a complete failure. Most beds filled with this compost produced no mushrooms and the others only an ounce per square foot.

While this experiment was in progress, we were informed that urea is not at present available for agricultural use in large quantities, but manufacturing capacity is being increased and supplies may be obtainable in 1952.

Table 6. Supplements per stack of 210 lb. dry straw

27 lb. dried blood.
21 lb. hoof and horn meal.
14½ lb. calcium cyanamide.
6½ lb. urea.
62 lb. hide and leather meal.
14 lb. dried blood and 3½ lb. urea.

Table 7. Sources of nitrogen in synthetic compost

	First picking days from spawning	Mushrooms/sq. ft.				Oz./sq. ft.			
		0-4	4-8	0-8	12 wks.	0-4	4-8	0-8	12 wks.
Dried blood	56	15·7	12·3	28·0	31·8	12·3	6·9	19·2	21·5
Dried blood + urea	56	19·4	14·8	34·2	37·6	13·0	7·8	20·8	23·2
Urea	58	19·7	10·7	28·4	29·4	14·9	5·3	20·2	22·0
Hoof & horn meal	58	14·1	8·7	22·8	25·2	13·5	5·5	19·0	21·0
Hide and leathermeal	60	10·9	6·4	17·3	19·6	10·1	3·9	14·0	15·5
	±1·3			±4·4	±5·3			±2·0	±2·5
Shelves—									
top	58	12·4	6·8	19·2	20·7	11·0	4·2	15·2	16·8
middle	58	16·0	11·2	27·2	30·2	12·8	6·5	19·3	21·9
bottom	59	19·4	12·8	32·2	35·2	14·6	6·8	21·4	23·2
	±0·55			±1·5	±1·8			±0·8	±1·0

Conclusions.

There was no significant difference between dried blood, urea, dried blood+urea, and hoof and horn meal, but hide and leather meal was inferior to all of these and cyanamide was useless. There was a greater loss of nitrogen from the urea compost during composting, as might be expected from a readily soluble and available substance.

Expressing yields on bed area or weight of manure

It is customary in Britain to express yields as pounds per square foot, whereas on the Continent and sometimes in America the normal measure is yield per ton of manure.

In each case there may be a tacit assumption that the figure used is a measure of the economic success or otherwise of the crop. In some cases this is certainly not justified, and in others it is debatable. However, it is desirable to be able to compare yields on both systems and it was suggested at the International Conference in May, 1950, that wherever possible research workers should state their yields in both forms. Accordingly this is done in Table 8, summarising yields for experiments 12-14. The figures given for synthetic composts on the fresh weight basis are calculated from the original dry weight and moisture content, which is about 75% of the fresh weight at stacking.

Table 8. Yields on area and weight of compost

Experiment No.	Treatment	Yield lb. per sq. ft.	Yield per ton of compost or manure at stacking		Notes
			lb./ton dry matter	lb./ton fresh weight	
12	A	1·9	770	192	synthetic horse manure as received—50% water
	B—F	2·4—2·7	700—770	350—385	
13		1·1—1·25	370—420	92—105	synthetic
14	Dried blood	1·3	390	98	Synthetic
	Blood+Urea	1·4	450	112	
	Urea	1·4	470	118	
	Hoof & Horn	1·3	400	100	
	Hide & Leather	1·0	270	68	

CHEMISTRY DEPARTMENT

S. Burrows and P. B. Flegg

SAMPLING

In view of the difficulties of sampling at the first turn and the large sampling errors at this stage (M.R.A. Report, 1949) it was decided to abandon the method in use and obtain the composition of the composts at stacking by calculation from the analysis of the various constituents. This method was employed in Experiment 14 and was performed as follows :—

The 72 straw bales used in this experiment were numbered with metal tags and their weights recorded. Eight of these bales were sampled by taking out four cores from each with a long $1\frac{1}{2}''$ diameter core sampler. Cores from each two bales were combined to give four samples which were analysed for moisture, total N, ash, acid-insoluble ash, calcium, potassium and phosphorus. After the bales had been wetted with the drip pipe and fermented, the same bales were again sampled, and analysed for moisture, ash, acid insoluble ash, calcium and potassium. The bales were divided into three groups according to their weights before wetting, and (by suitably grouping the bales) approximately the same weight of straw was put into each of the 24 stacks.

The activators to be used were thoroughly mixed beforehand, sampled, and analysed for total N, ash, acid-insoluble ash, calcium, potassium and phosphorus. From these results the following data were calculated.

Loss of dry matter in straw during the preliminary fermentation.

Dry matter in each stack at stacking and limits of error.

Nitrogen, potassium, phosphorus, calcium and ash in each compost at stacking.

The mean results for the six composts in each treatment are given in Table 9. After allowing for the variation of moisture content of the straw the standard error of the dry weight of straw in each bay was $\pm$ 5·5 lb., but taking the different treatments separately the standard error of the dry weight of straw per bay within compost treatments was $\pm$ 2 lb. or 1% of the total dry weight. These errors depend entirely upon the variations in moisture content of the straw and upon the degree to which the straw weights in the stacks are equalised. The potassium content of the original straw was very uniform (1·00% $\pm$ ·02) but after wetting with the drip pipe about 15% of it was lost by leaching and the amount remaining was much more variable (0·92% $\pm$ ·13) calculated on the dry matter in the fermented straw. It is probable that more potassium was lost during the further wetting of the straw when it was stacked with the activators. The loss of dry matter during the fermentation of the baled straw, estimated from the acid-insoluble ash of the four pairs of samples taken, was very variable. The lowest loss was 1·5% of the original weight and the highest 21% giving an average weight of fermented straw in each stack of 149 $\pm$ 10 lb. derived from 164 $\pm$ 5·5 lb. dry weight of original straw.

Table 9. Experiment 14. Mean composition of composts at stacking calculated from composition of straw and activators

Compost treatment (Nitrogen source)	Dry weight of activators lb.	Mean dry weight of straw lb.	Calculated mean composition of composts at stacking					
			Total dry matter using original straw weight	% total N	% calcium	% acid insoluble ash	% of potassium	% phosphorus
Dried blood	33·7	162 ± 2	196 ± 2	2·03	1·42	4·78	0·89	0·12
Hoof and horn	29·4	163 ± 2	192 ± 2	1·80	1·77	5·01	0·97	0·10
Calcium cyanamide	24·4	163 ± 2	187 ± 2	1·84	2·20	5·16	0·96	0·074
Urea	16·5	166 ± 2	183 ± 2	1·97	1·73	5·27	1·07	0·09
Hide and leather	64·8	165 ± 2	230 ± 2	1·86	1·29	4·26	0·77	0·079
Dried blood and urea	25·8	164 ± 2	190 ± 2	2·08	1·63	5·02	0·96	0·097
	Moisture%	Dry weight lb.	Potassium %					
Straw — Original	22·2 ± 2·0	164 ± 5·5	1·09					
Straw — After wetting and heating	54·8 ± 5·7	149 ± 10	0·92					

To make allowance for loss of potassium by leaching during the wetting and heating of the straw the % of potassium in the straw after wetting and heating was calculated as a percentage of the original dry weight of the straw, i.e., 0·83%

METHODS OF ANALYSIS

Potassium. The turbidimetric method of determining potassium has usually given good results, but occasionally low results have been obtained ; the reason for this is being sought. Meanwhile the determination is being carried out by precipitation of potassium cobaltintrite and titration of the precipitate using standard cerium sulphate.

Nitrogen. The nitrate recovery of the present method (using salicylate and thiosulphate) of estimating nitrogen has been investigated and compared with two other methods. 20 g. of a sample of well mixed fresh compost was used in each determination. The nitrate recovery was found by adding 0·1 g. sodium nitrate to the compost, which with complete recovery would give an increased titration reading of 2·35 ml. 0·5 N hydrochloric acid. The use of Devarda's alloy was investigated both before digestion and during distillation. (Table 10).

Table 10. Recovery of nitrate

	Treatment		Titration 0·5N acid	Mean s.e. ±0·30
	Digestion	Distillation		
20 g. fresh compost	20 g. sodium sulphate 1·0 g. sodium salicylate 0·5 g. sodium thiosulphate + selenium 70 ml. concentrated sulphuric	160 ml. 60% sodium hydroxide	15·25 ml. 15·40 ml 15·30 ml.	15·32 ml.
20 g. fresh compost 0·1 g. sodium nitrate	as above	160 ml. 60% sodium hydroxide	17·05 ml. 16·30 ml. 17·10 ml.	16·82 ml.
20 g. fresh compost 0·1 g. sodium nitrate	as above	160 ml. 60% sodium hydroxide +2 g. Devarda's alloy	15·30 ml. 16·90 ml. 15·70 ml.	15·97 ml.
20 g. fresh compost 0·1 g. sodium nitrate	30 ml. N sulphuric acid 15 ml. water 2·0 g. Devarda's alloy reduction for 30 mins. then digested without the addition of salicylate or thiosulphate	160 ml. 60% sodium hydroxide	16·85 ml. 17·25 ml. 17·85 ml.	17·32 ml.

Nitrate recovery using the present method was 63·8% compared with 85·1% using Devarda's alloy to reduce nitrates before digestion.

There is very little information regarding the nitrate content of composts. Results so far tend to indicate that it is low but rises throughout the several stages of mushroom production. In future nitrogen will be estimated using Devarda's alloy to reduce any nitrate present before commencing digestion.

RESULTS

Oxalate. In Experiment 1 a negative correlation was found between dry matter loss and oxalate formation during cropping. It was suggested that this could be explained by reassimilation of oxalate by the mushroom mycelium in the compost. Further work with synthetic composts has confirmed the fact that the oxalate first formed disappears later in the cropping period, but other organisms may be concerned in its disappearance.

Very large and at first sight inexplicable variations in oxalate content were found with most of the synthetic composts and the apparently haphazard nature of the results is well exemplified in the case of Experiment 5. These results are given in Table 11, where each block contains the figures for three beds from each compost.

There appeared to be a possibility that high yields resulted in low oxalate values in this experiment, although there were many discrepant figures. A re-examination of the figures for Experiments 5, 9 and 10 together, remembering the possibility of reassimilation of oxalate, suggested that an early start of cropping might also lead to low oxalate values. Since the number of days between spawning and the first picking of mushrooms had been recorded it was thus possible to calculate total correlations and partial correlations between pairs of the three sets of variables, namely, oxalate, yield and days to first picking. In the case of Experiment 1, the twelve beds containing untreated compost were chosen and the effect of dry matter loss on oxalate, already established, was eliminated as well. Table 12 gives for Experiments 1, 3, 5, 9 and 10 the partial correlations between oxalate and yield, and oxalate and days to first picking. For the latter correlation

Table 11. Experiment 5. Oxalate content of exhausted beds

Calcium oxalate ($CaC_2O_4.H_2O$) expressed as per cent. of dry matter at filling

	No Supplement		Beet tailings		Castor bean meal	
75% nitrochalk 25% blood meal	0·65	1·34	·038	0·10	1·65	1·23
	0·07	0·74	nil	nil	nil	nil
	0·14	1·42	·021	nil	1·49	0·68
25% nitrochalk 75% blood meal	nil	0·06	0·02	nil	nil	nil
	nil	nil	nil	nil	nil	nil
	nil	0·05	nil	0·05	0·03	0·10

the corresponding z values and their variance, for the purpose of calculating the mean z values over all the experiments, are also given. Although the correlation co-efficients for the oxalate—days to first picking association are all low, indicating a weak correlation, yet taking all the experiments together an effective sample size of 87 beds is obtained showing a very significant correlation between these two variables.

Table 12. Collected oxalate correlations

Oxalate % of dry matter at end of crop, yield lb./sq. ft., days from spawning to first picking

Experiment	Oxalate yield correlations		Oxalate/ days to 1st picking correlations (r_2)	Z value corresponding to r_2	Number of beds analysed	Variance of Z	Z / Variance of Z
	r_1	P					
1. Untreated composts only	+·569	>·1	+·534	+·596	12	·143	+4·102
3. 7 composts only	—·178	>·1	—·086	—·086	21	·059	—1·462
5. All beds not misted	—·505	<·01	+·302	+·312	36	·031	+9·984
9. Composts with P added at filling	+·589	<·01	+·359	+·375	24	·05	+7·500
11. Beds cased late, mushrooms picked closed	—·113	>·1	+·354	+·370	12	·125	+2·960
				Total			+23·084
				Weighted mean z			+0·275
				Standard error of z			·109
				P			·012

The effect of yield is very variable from experiment to experiment and no definite conclusions can be drawn from the figures. The positive co-efficient in Experiment 1 is probably due to the complicating effect of depth and that in Experiment 9 may be due to the fact that this was the only experiment which was ended before cropping was complete. In Experiments 5 and 9, the two variables, yield and days to first picking, account for most of the variations which at first sight appeared somewhat haphazard.

These results show that, although yield may be a complicating factor, the oxalate in the spent compost is lower with an earlier crop than with a later one. This strongly supports the evidence from the deep and shallow beds of Experiment 1 that oxalate is reassimilated during the latter part of the cropping period. The core samples taken at 5 and 10 weeks after spawning and at emptying, from one block of composts in Experiment 11, are interesting in this connection. Since no great differences between the top, middle and bottom sections were observed, the mean figures only are given in Table 13. A rapid rise in oxalate content was observed during the initial spawn run until, in the case of the A and B composts, about 1·6% was formed, when the amount seems to have altered little. For the C compost the rise was not so rapid, whereas D showed a big fall in oxalate between the 10th week and the end of cropping. The reasons for this drop in the case of the D compost may be that the onset of cropping was rather earlier for this compost and that cropping practically ceased after the 8th week in marked contrast to the other composts in this block and also in contrast to most of the other D composts. All that can be said with certainty is that under certain ill-defined conditions oxalate is re-assimilated. The possibility of its absorption by other organisms present in the compost cannot be ruled out.

Table 13. Experiment 11. Oxalate changes

Compost treatment, period of composting	Oxalate (% of dry matter at filling)			Yield lb./sq. ft.	Days from spawning to 1st picking
	5 weeks	10 weeks	31 weeks (at emptying)		
A/4 6 weeks	0·51	1·60	1·67	2·09	54
B/4 5 weeks	0·56	1·57	1·54	2·56	50
C/4 4 weeks	0·50	0·80	1·74	2·33	54
D/4 3 weeks	0·32	1·33	0·11	1·60	49

Experiment 12. Dry matter losses during composting

In this experiment an attempt was made to obtain a more accurate estimate of dry matter losses by adding sand (15 lb. per 6 cwt. stack) to half of the stacks in order to increase the acid-insoluble ash. In the racing stable manure however there was a quantity of stones present and samples showed a big variation in acid-insoluble ash figures so

that no reasonable estimate of dry matter losses could be obtained from the acid-insoluble ash. The acid-soluble ash figures were far more uniform and by using these and correcting for the soluble ash in the added activators, estimates of dry matter loss were obtained. The means for each compost treatment and each block are given in Table 14, together with the mean dry matter loss during peak-heating for blocks 1 and 2 only, and also the mean maximum temperatures during composting. There is no relation between composting losses and peak-heating losses although the latter are small and of the same magnitude as for fully composted synthetic compost in Experiment 11 (M.R.A. Report, 1949). The most important differences in dry matter loss during composting are between the east and the west side of the composting shed and appear to be caused by external conditions producing variations in compost temperatures (see Figure 1). Taking each stack separately there is a significant positive correlation between dry matter loss and temperature ($r=+\cdot707$, $n=22$, $P<\cdot01$) Table shows that a 9° C. rise in the composting temperature (from 60° to 69° C., 140° to 156° F.) resulted in an increase from 27% to 38% in the dry matter loss or a 25% increase in the rate of fermentation.

The low dry matter loss in the composts to which nitrochalk was added may be due to the low nitrogen/calcium ratio. This ratio was shown to be of importance in Experiment 9 (M.R.A. Report, 1949) and is further discussed under Experiment 14.

There were considerable variations in moisture content of the composts in this experiment. The relation between dry matter per sq. ft. of bed and yield is discussed on p. 9. The relevant figures are given in Table 15.

Table 14. Experiment 12. Dry matter loss during composting and peak heating

Compost treatment	Dry matter loss %		Mean max. temp. during composting °C.	N/Ca ratio
	Composting	Peak-heating		
A. M.R.A. synthetic	31	6	59	—
B. R.S.M. alone	36	3	64	1·2
C. R.S.M.+nitrochalk....	23	5	64	0·8
D. R.S.M.+activator A	37	4	65	1·2
E. R.S.M.+activators A+B	34	3	65	1·2
F. R.S.M.+activators A+B+C	35	0	66	1·2
Block I (East)	38	4	68	—
Block II (East	38	2	70	—
Block III (West)	26	not	60	—
Block IV (West)	28	determined	60	—

Figure 1—Experiment 12—Effect of compost temperature on dry matter loss during composting

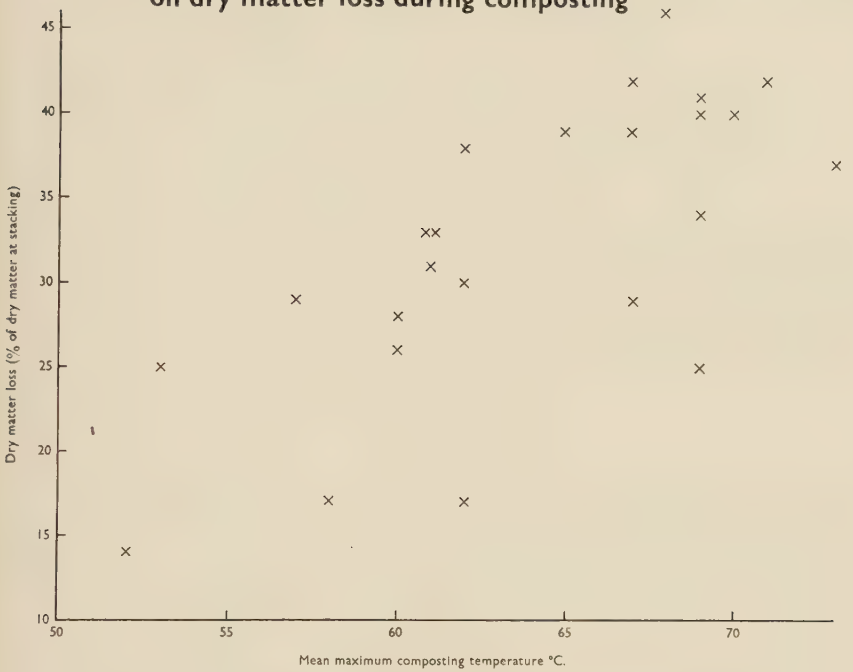


Table 15. Experiment 12. Total N, density, and yield

Compost treatment	Total N % dry matter at filling	Dry density (lb./sq. ft. bed area at 8″ deep)	Yield lb./sq. ft.	Yield lb./lb. dry matter in compost at filling
M.R.A.	2·46	3·5	1·9	0·54
R.S.M.	2·16	4·7	2·4	0·52
R.S.M.+nitrochalk	2·55	4·8	2·6	0·53
R.S.M.+activator A	2·59	5·0	2·5	0·50
R.S.M.+activator A+B	2·72	4·8	2·7	0·56
R.S.M.+activator A+B+C	2·77	4·6	2·7	0·58

Experiment 13

The low yields in this experiment cannot be definitely associated with any of the analytical data although both total nitrogen and dry matter losses during composting were low (see Table 16). The twelve composts which were peak-heated showed more normal total dry matter losses but this was not reflected in increased yields. In fact the yields from the peak-heated composts were somewhat lower than from those not peak-heated. These results are not in agreement with the inference drawn from Experiment 11 (M.R.A. Report, 1949).

Table 16. Experiment 13. Total N and dry matter losses

Compost treatment	Total N at filling	Dry matter loss (% of dry matter at stacking)		Total d.m. loss	12 weeks Yield oz./ sq. ft.
		Stacking to filling	During peak heating		
4 weeks composting, peak-heated	2·04	27	13	40	18·2
3 weeks composting, peak-heated	2·02	18	14	32	16·0
4 weeks composting, not peak-heated	2·30	29	—	29	20·7
3 weeks composting, not peak-heated	2·00	14	—	14	19·5

Experiment 14

The composition of the composts at stacking was obtained by the method already given (p. 14) and the dry matter losses during composting were calculated from the acid-insoluble ash figures at stacking and at filling. There were significant differences between the dry matter losses in the six compost treatments and Table 17 indicates that the nitrogen-calcium ratio may be responsible for these differences. When the mean dry matter loss was plotted against the N/Ca ratio five of the results were found to lie on a smooth curve but the sixth (corresponding to the hide and leather meal composts) was considerably below the curve, these composts giving lower dry matter losses in this and a previous experiment (No. 10, Figure 2). (If calcium and not N/Ca ratio is plotted the points are much more scattered). The racing stable composts in Experiment 12 showed a similar effect and these results are included in Figure 2, together with those for Experiment 9 where two levels of calcium and two levels of nitrogen were used (M.R.A. Report, 1949). In the latter experiment a maximum dry matter loss was obtained with a N/Ca ratio of 1·1 with a lower loss both above and below this value. A similar inflection did not occur in the curve for Experiment 14 although this possibility was not excluded since the curve appeared to flatten at high N/Ca values.

Apart from composting temperatures, which were not measured, the factors known to affect nitrogen losses during composting, namely, total nitrogen and carbon-nitrogen ratio were fairly uniform. In spite of this there were highly significant differences in nitrogen losses between the composting treatments (Table 17). The big losses from the urea composts are probably due to the fact that urea can be rapidly converted microbiologically into ammonia, some of which would then be lost before it could be reassimilated. The lowest losses of nitrogen were from the hoof and horn meal and the cyanamide composts, both of which also showed the lowest dry matter losses.

Figure 2—N/Ca ratio and dry matter loss during composting

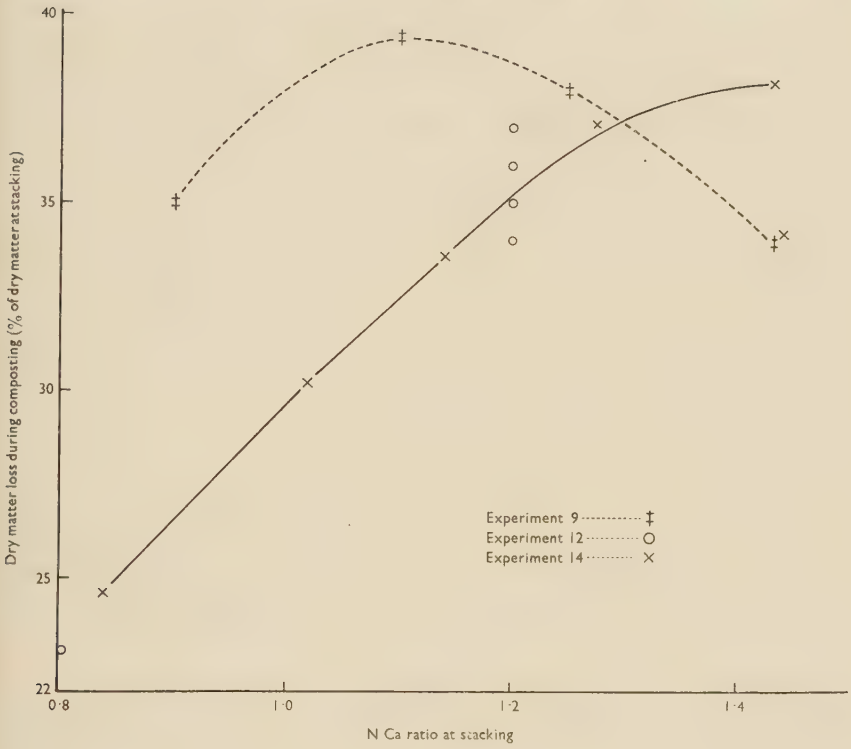


Table 17. Experiment 14. Loss of nitrogen during composting

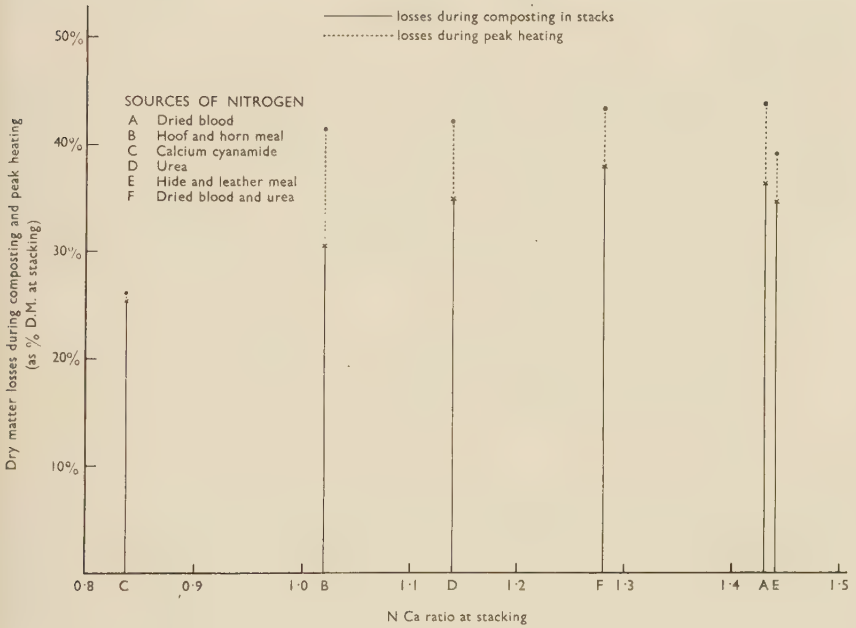
Compost treatment (Nitrogen source)	Total nitrogen (mean of four stacks)				C/N ratio at stacking
	At stacking	At filling		Loss of nitrogen %d.m. at stacking	
		% d.m. at filling	% d.m. at stacking		
Dried blood	2·03	2·51	1·54	0·49	22
Hoof and horn	1·80	2·36	1·63	0·17	24
Cyanamide	1·84	2·16	1·64	0·20	21
Urea	1·97	1·46	0·97	1·00	20
Hide and leather meal	1·86	2·11	1·38	0·48	24
Dried blood and urea	2·08	2·46	1·50	0·58	21
Standard error of mean				±0·09	

Dry matter losses during peak-heating were also determined upon two out of the four stacks in each treatment and are shown in Table 18. Figure 3 showing the relation between dry matter losses during composting and dry matter losses during peak-heating shows that four of the composts confirm the findings of Experiment 11 (M.R.A. Report, 1949) that peak-heating tends to level up total dry matter loss. It is interesting to note that the two composts which deviate from this are the cyanamide compost which did not yield at all and the hide and leather meal, the yield from which was significantly lower than the others. It is known that calcium cyanamide contains a small amount of mineral oil which may have had an inhibitory effect either on the organisms generally active during composting or upon the mushroom mycelium.

Table 18

Compost treatment (Nitrogen source)	N/Ca ratio at stacking	D.M. loss% during composting (mean of 4 stacks)	Total D.M. loss % stacking-peak heating (mean of 2 stacks)	D.M. loss% during composting (mean of 2 stacks)	D.M. loss% during peak heating (mean of 2 stacks)	Yield 8 weeks oz./sq. ft.
Dried blood	1·43	38·2	43·39	36·3	7·09	19·2
Hoof and horn meal	1·02	30·2	41·45	30·5	10·95	19·0
Calcium cyanamide	0·84	24·6	26·05	25·75	0·30	—
Urea	1·14	33·6	42·18	34·9	7·28	20·2
Hide and leather meal	1·44	34·2	39·15	34·7	4·45	14·0
Dried blood and urea	1·28	37·1	43·38	37·9	5·48	20·8
Standard error of the mean			±2·4	±4·01		±2·0

Figure 3—Dry matter losses during composting and peak-heating



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CASING SOIL—P. B. Flegg

A preliminary survey has been made of the moisture range of the casing soil on the beds during cropping and the evaporation of moisture from soils under mushroom growing conditions. This was done in order to obtain information on which to base future cropping experiments. Also as the function of the soil appears to depend largely on its physical properties, methods of measuring the pore space, moisture holding properties, structure, and stability have been and are being developed.

Evaporation of moisture from soil

The M.R.A. casing soil is made up of 7 parts of clay-loam subsoil dug from 2-3 feet, and one part of sand. About 2% of hydrated lime is added. This gives an approximate composition of 87·5% clay-loam subsoil and 12·5% sand. Drying-out curves for this and several other mixtures of clay and sand were obtained in order to get some idea of the effect of additions of sand on the water holding capacity. The mixtures were based on oven-dry weight but were actually mixed in moist condition with care not to break up the lumpy structure of the clay. The soils used were :—

clay loam subsoil
M.R.A. casing soil. 87½% clay loam subsoil+12½% sand
75% clay loam subsoil+25% sand (C/S)
50% clay loam subsoil+50% sand (50/50)
25% clay loam subsoil+75% sand (S/C)
Sand

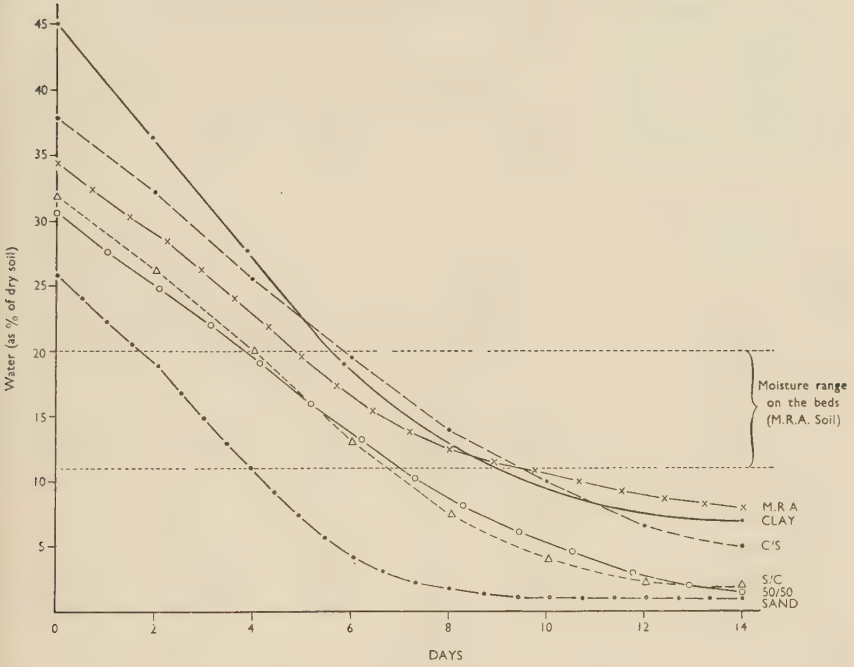
The soils were placed in round tins 1·7 cm. deep and surface area 300 sq. cm. each holding 400—600 g. of soil. The tins were replicated and set out in the form of a Latin square to allow for possible differences due to position in relation to heating and ventilation. The soils were wetted approximately to saturation point with a watering can and the daily loss in weight of each tin was recorded. The daily losses from tins containing water were used as controls. During the experiment the temperature of the house varied between 21° and 10° C.

Figure 4 shows some typical drying-out curves. The clay and sand appeared to dry out more rapidly than the mixtures during the first five days. Total evaporation of water does not occur under these conditions; the soils with a high proportion of clay retained 4·5% moisture or more (expressed as % of the weight of dry soil) and those with up to 50% clay retained 2% moisture or less.

The M.R.A. soil which differed from the other mixtures in having been limed, retained 8% moisture, more than the clay loam subsoil.

The mean moisture content of soil on beds has been found to vary under normal management from 11% just before watering to 20% just after watering. From Figure 4 it can be seen that the M.R.A. soil remains within this range for four days. In practice, at the time of this experiment, the beds in the house were watered once every 3-4 days. Of the other soils the C/S mixture was within this range for 3⅔ days, the clay alone 3 days and the sand 2 days, thus the addition of up to 25% sand to the clay seemed to increase the moisture holding capacity of the soil within this moisture range found on the M.R.A. beds.

Figure 4—Drying curves for soil mixtures



However, the moisture range 11% to 20% found to be suitable using the M.R.A. soil mixture may not be the optimum range for more sandy soils. From Table 19 it is seen that the range 11% to 20% falls just below the Moisture Equivalent of either the clay loam subsoil or C/S mixture, whereas for the sand it lies above the moisture equivalent. The sand would be very nearly waterlogged with 20% moisture ; if the moisture equivalent determines its maximum water content permissible on the bed this would be about 7%, which is less than the observed working variation in moisture content of the heavier soil.

Examination of the rate of loss from the water controls showed a fairly constant rate of evaporation with exception of the 7th to 12th days. As this happened in all controls it does not invalidate comparison between the different soils.

Soil Structure and Stability

It is well known that some soils do not stand up to the continual watering to which they are subjected on a mushroom bed. They tend to break down from a lumpy structure to a fine powder. This then cakes, forming a hard crust on the bed, retarding the passage of oxygen and carbon dioxide.

In order to obtain some measure of the structure and stability of casing soils, a simple wet sieving technique has been developed. The soil is carefully wetted by capillary action for 30 minutes to prevent breakdown due to compressed air bubbles when immersed in water.

Table 19. Moisture holding and related properties of soil mixtures

(Means of 4 determinations. Suction time 15 minutes)

Soil Mixture	Moisture Equivalent %	Standard error of mean	Maximum Water Holding Capacity %	Standard error of mean	Pore Space %	Standard error of mean	Capillary Pore Space %	Non-capillary Pore Space %
C 100% clay-loam subsoil (Yaxley)	26·70	± 0·41	45·17	± 0·63	48·85	± 0·19	28·75	20·10
C/S 75% clay-loam subsoil 25% sand	24·80	± 1·56	41·24	± 1·14	46·44	± 0·75	—	—
50/50. 50% clay-loam subsoil, 50% sand	19·70	± 0·59	37·70	± 1·30	43·81	± 0·63	23·0	20·81
S/C 25% clay-loam subsoil, 75% sand	15·50	± 1·18	30·48	± 1·50	39·75	± 1·06	—	—
S 100% sand	7·62	± 0·21	24·03	± 0·48	35·44	± 0·63	11·25	24·19
M.R.A. mixed soil	29·9	± 0·98	43·36	± 0·45	48·31	± 0·19	—	—

It is transferred carefully to a 2 mm. sieve and then slowly raised and lowered in water a given number of times at the approximate rate of once per second. The dry weight of the soil remaining on the sieve after this treatment is found and expressed as a percentage of the original dry weight of the soil taken, and is a measure of the state of aggregation of the soil. Tables 20 and 21 show some of the preliminary results obtained by this method. There are as yet insufficient data to relate the results to practice and certain modifications of the method may be necessary.

It is known, however, that the M.R.A. soil does not break down during cropping and the Shropshire soil with poor structure does. The grower reports that this soil forms a "pan" after about the fifth watering which is about 15 days after watering commences. As the cropping period is 70 days this means that for the greater part of the cropping period the exchange of gases through the soil may be relatively impeded.

Table 20

Wet Sieving. The effect of increasing number of immersions using the M.R.A. casing soil

No. of immersions	State of Aggregation (mean of 3)	Standard error of means
25	62·4%	
50	54·3%	± 4·9
100	51·4%	

Table 21. State of aggregation of three different soils (50 immersions each)

Soil	State of Agregation (mean of 3)	Standard error of means
M.R.A. soil clay—large lumps	53·5%	
A Kent soil clay—small lumps	46·2%	± 2·3
A Shropshire soil sandy—poor stability	23·5%	

New Combined Method for the Determination of Pore Space, Moisture Equivalent and Maximum Moisture Holding Capacity of Soils

This method was devised by J. Tinsley of the University of Reading and is in the process of being developed both at Reading and in the laboratory. It combines the Pore-space Maximum Moisture Holding Capacity method of Keen and Raczowski (1921) and a Moisture Equivalent method of Bouyoucos (1929, 1935).

The dried, ground [illegible] mm. sieve soil is placed in a brass cylinder with a perforated base plate and is packed to [illegible] by tapping. A filter

paper in the bottom of the cylinder prevents loss of soil. The cylinder is then immersed in water to within $\frac{1}{8}$" of the top and the soil allowed to soak for 18-24 hours. When thoroughly waterlogged the soil in the cylinder is levelled off with a sharp edge and weighed. Steady suction (36·8 cm. of mercury) equivalent to a pF of 2·7 is then applied to the cylinder for 15 minutes and the cylinder is again weighed, then oven dried and re-weighed. More recent work has shown that 30 minutes suction is the best time.

From the readings obtained it is possible to calculate :—

$$\text{The Moisture Equivalent} = \frac{\text{weight of water retained at pF 2·7}}{\text{weight of oven dry soil}}\%$$

$$\text{Maximum Water Holding Capacity} = \frac{\text{weight of water present when soil is water-logged}}{\text{weight of oven dry soil}}\%$$

$$\text{Pore Space} = \frac{\text{total volume of water present when soil is water-logged}}{\text{Volume of cylinder}}\%$$

Following the work of Sekera (1938), who has calculated that water held by the soil against a suction pressure of approximately $\frac{1}{3}$ atmosphere fills pore spaces less than 3μ, it is possible to calculate an arbitrary figure representing the " Capillary Pore Space " of the soil :—

$$\text{Capillary Pore Space} = \frac{\text{Moisture present at pF 2·7}}{\text{Volume of cylinder}}\%$$

and Non Capillary Pore Space = Total Pore Space—Non Capillary Pore Space.

Table 19 shows a series of results obtained with the clay-sand mixtures used in the experiment on rates of evaporation. As expected the Maximum Moisture Holding Capacity and Moisture Equivalent fall as the proportion of sand present increases. The capillary pore space decreases in a similar manner whereas the non-capillary pore-space remain fairly constant in all samples. Thus the water holding capacity of these samples seems to depend largely upon the capillary pore space.

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MICROBIOLOGY DEPARTMENT

Miss C. Duncan

Experiments on Truffle, *Pseudobalsamia microspora.* Diehl and Lambert.

Former experiments have suggested that pH and moisture content play a great part in conditions under which Truffle will flourish. The importance of pH has not been separated from the influence exerted by moisture. Previous attempts had shown that composts treated to produce widely varying pH tend to level out towards neutrality. Efforts to buffer compost with 10 N acetic acid and sodium acetate, were abandoned as it became increasingly obvious that the pH did not remain static for any length of time.

Experiments were then set up to find and test a fungistatic or fungicidal substance which would prevent Truffle spore germination. The first group of fungicides selected for trial consisted of lime-sulphur, sulphur, colloidal sulphur, Parzate, and thiourea.

Compost was peak-heated in an incubator and later a sample was taken for determination of moisture content. Fungicides were made up to the required strengths and when sprayed on to the compost, brought the moisture content from 61·5% to 68%. The fungicides were tested in the following concentrations, based on the wet weight of compost.

Lime sulphur	1% and 10%
Sulphur	0·1% and 1%
Colloidal sulphur	0·2% and 2%
Parzate	0·01% and 0·1%
Thiourea	0·01% and 0·1%

25 ml. of each concentration of fungicide was sprayed on to 125 g. of compost and packed into six tubes, making sixty-six tubes with the addition of six control tubes, which were sprayed only with water. The tubes were then spawned with pure culture mushroom spawn, plugged with cotton wool and incubated at 25° C.

After about five days, all tubes were marked with a white line, where the fringe of mushroom mycelium was actively growing. Daily measurements and comparison with the control tubes ensured that any substance retarding mushroom mycelial growth would be found fairly quickly and discarded.

The range of measurements in the tubes treated with 10% lime sulphur was so great that they were discarded. The stronger concentrations of colloidal sulphur, Parzate and thiourea were also discarded because mushroom mycelial growth was very slow. Later, tubes treated with the 1% lime sulphur were abandoned for the same reason.

Two weeks after spawning, the remaining tubes were "cased" with a mixture of Truffle fruiting bodies and compost, already prepared by the method mentioned in the last report (Glasscock & Ware, 1941). All were then incubated at 29° C., the optimum temperature for growth of Truffle. Just over a week later, the first Truffle infected tube was discovered in the batch of tubes treated with 0·2% colloidal sulphur.

Infected tubes were discovered daily until about two months from the date when the experiment was set up. Of the groups remaining, control tubes and those treated with 0·01% Parzate and with 0·01% thiourea showed 100% infection, whilst in each group treated with 0·1% sulphur and 0·2% colloidal sulphur, only one out of 6 tubes remained free from Truffle.

In Figure 5 the growth curve of the mushroom mycelium in the control tubes is the best ; in 0·01% thiourea, 0·1% sulphur, 0·01% Parzate and 0·2% colloidal sulphur, growth started at the same rate ; after about 11 days growth began to fall off in 0·01% Parzate and 0·2% colloidal sulphur.

1% sulphur has not been included in the graph, because measurements of the mushroom mycelium were impeded by contamination at an early date.

These substances had not prevented Truffle spore germination, but the success of the infection technique provided a useful and fairly reliable test for further experiments.

A further series of substances was tested :—

Copper sulphate	....	0·01% and 0·1%
Boric acid	....	0·1% and 1%
alpha-naphthol	....	0·1% and 0·01%

Unfortunately, the moisture content was not determined, but probably the compost was drier than that used in the previous experiment, and the time of adding the fungicides was changed. A known volume of each fungicide was sprayed on to a known weight of compost, and the whole packed into six tubes, plugged with cotton wool and peak-heated for 36 hours. The fungicides were sprayed on before peak-heating this time so that the addition of excess moisture could be counteracted by peak heating. A batch of controls was included as before.

After cooling, the tubes were spawned with pure culture mushroom spawn and incubated at 25° C. About a week later each tube was marked with a white line and mycelial growth was measured daily, as before. Tubes treated with 1% boric acid were discarded almost immediately as mushroom mycelium never penetrated the compost.

After a further two weeks all tubes were ' cased ' with Truffle-infected compost, except the batch treated with 0·1% boric acid in which mushroom mycelial growth was very slow. After ' casing,' the tubes were incubated at 29° C.

About a month later three tubes out of six in each of the groups treated with 0·1% and 0·01% alpha-naphthol were found to be Truffle-infected, and four in the control group. No infected tubes were found in the batches treated with 0·1% and 0·01% copper sulphate.

Figure 6 shows that mycelial growth in the tubes treated with 0·1% and 0·01% alpha-naphthol, started very slowly. After 8 days, growth in the 0·01% alpha-naphthol increased considerably. Growth in the other three composts treated with 0·1% and 0·01% copper sulphate, and water, proceeded at approximately the same rate until the seventh day of measurement when growth appeared to slacken off in the stronger concentration of copper sulphate, and the curve finished below that of

Figure 5—Growth curve of mushroom mycelium through treated compost

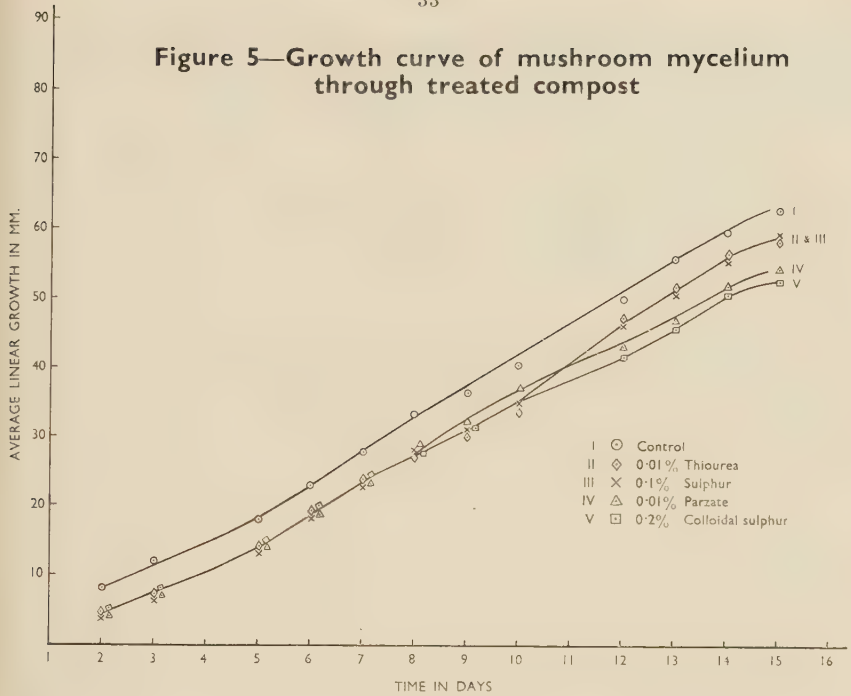
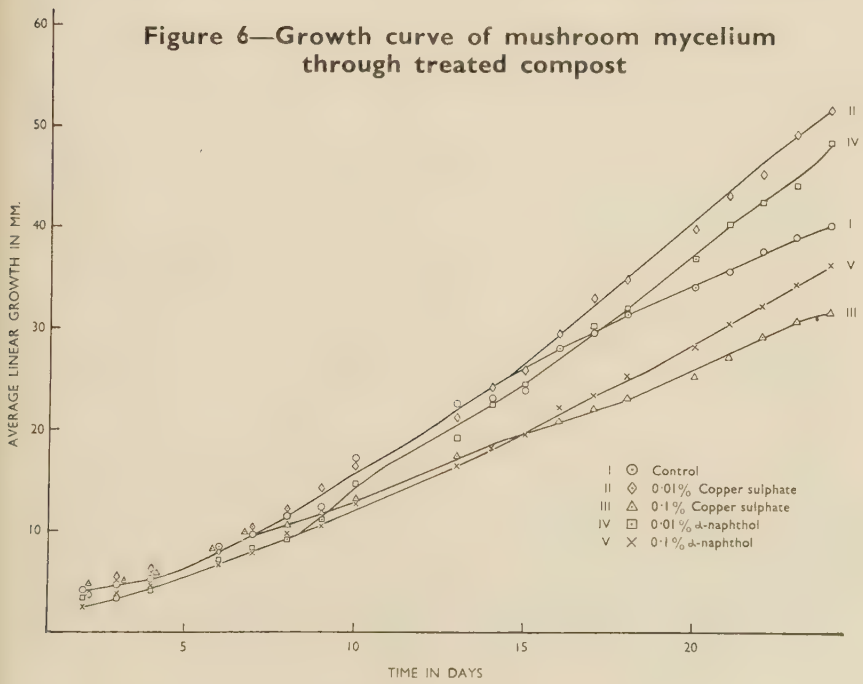


Figure 6—Growth curve of mushroom mycelium through treated compost



the 0·1% alpha-naphthol treated compost. The other two continued together until the 15th day when growth in the 0·01% copper sulphate-treated tubes increased steadily, relative to the control.

Other copper compounds were included in the next experiment :—

Bordeaux mixture
Burgundy mixture
Copper sulphate 0·01% and 0·1%
Copper 8-quinolinolate 0·05% and 0·5%
Boric acid 0·001% and 0·01%

The moisture content of the compost used in this experiment was 75%, which is rather high. The routine followed that of the last experiment described—the fungicide being sprayed on to the compost before peak heating. The tubes were spawned and incubated at 25° C. and mycelial growth was measured daily. Those treated with 0·001% and 0·01% boric acid were discarded because of the very slow rate of growth of mushroom mycelium.

Two weeks after spawning, three tubes from each group of six were ' cased ' with Truffle-infected compost. About two weeks later Truffle appeared in a single tube treated with Bordeaux mixture. Seventeen days after ' casing ' all tubes treated with Bordeaux mixture, Burgundy mixture and the controls were infected. Two out of three tubes treated with both concentrations of copper 8-quinolinolate were Truffle-infected, also two of those treated with 0·01% copper sulphate and one in the 0·1% copper sulphate-treated group. These tubes treated with both concentrations of copper 8-quinolinolate and copper sulphate became infected much later than the other tubes and the percentage infection never increased though the tubes were incubated for the full two months from the beginning of the experiment to the end.

In Figure 7 growth of mushroom mycelium in compost treated with 0·05% copper 8-quinolinolate appears to be best. The growth rate in the composts treated with 0·01% and 0·1% copper sulphate was about the same for six days, then growth in the 0·01% copper sulphate treated compost increased markedly. Growth in the tubes treated with 0·5% copper 8-quinolinolate was normal for 9 days, and then became slower. Growth in the tubes treated with Burgundy mixture was slower than in controls throughout the experiment.

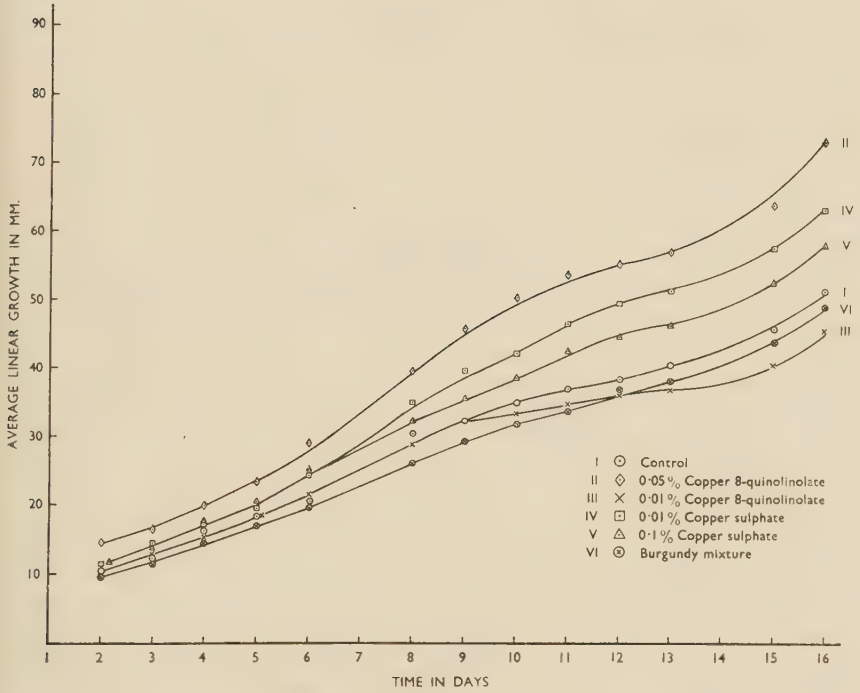
Growth in the compost treated with Bordeaux mixture has not been included in the figure, because the growth curve was very erratic. It started off at approximately the same rate as that treated with copper sulphate, and then gradually fell off, ending just ahead of the control.

Another experiment was set up in which 0·2% and 0·1% tetramethylthiuram disulphide (TMTD) and 0·1% and 0·01% Dithane Z.78 (containing zinc ethylene-bis-dithiocarbamate) were sprayed on the compost. These fungicides were applied before peak-heating as in former experiments. Comparisons showed that mushroom mycelium grew best in 0·1% tetramethylthiuram disulphide, but not so well as in the controls. Growth was very poor in both concentrations of Dithane Z.78 and these tubes were never ' cased ' with Truffle material. Truffle ascocarps developed in all the tubes treated with TMTD.

All these experiments will be repeated under more strictly controlled experimental conditions. Slight alterations to the method used will provide a satisfactory means of testing for selective action of fungicides. Any fungicide which harms the mushroom mycelium itself will be quite useless for use deep in the compost.

One fact has emerged, that under certain, at present undefined, conditions 0·01% and 0·1% copper sulphate treated compost allows mushroom mycelium to grow freely and has inhibited growth of Truffle on one occasion.

Figure 7—Growth curve of mushroom mycelium through treated compost


AVERAGE LINEAR GROWTH IN MM.
TIME IN DAYS
I ⊙ Control
II ◇ 0·05% Copper 8-quinolinolate
III × 0·01% Copper 8-quinolinolate
IV ⊡ 0·01% Copper sulphate
V △ 0·1% Copper sulphate
VI ⊛ Burgundy mixture

Advisory Work

The same fungi have been found this year, in samples received from members for examination, but not in such large numbers. *Sporendonema sp.*, *Verticillium spp.* and *Mycogone sp.*, which appeared during the warm weather, particularly August and September of 1949, appeared in the correspondingly warm periods of this year during May and June. Vert-de-gris appeared mainly over the same period as last year from the early part of the year up to July.

Fungi Identified on Mushrooms or Mushroom Beds

Parasitic on Mushroom

Mycogone perniciosa
Verticillium malthousei
Verticillium psalliotae

Competitors or Invaders (not necessarily harmful)

Arthrobotrys oligospora
Ascobolus furfuraceous
Chaetomium sp.
Monilia sp.
Oedocephalum fimetarium
Panaeolus sp.
Penicillium sp.
Peziza omphalodes
Pseudobalsamia microspora
Scopulariopsis fimicola
Sporendonema sp.
Thielaviopsis basicola
Trichoderma viride
Vert-de-gris
Xylaria vaporaria

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DISEASE CONTROL TRIALS ON COMMERCIAL MUSHROOM FARMS

Miss C. Duncan and R. L. Edwards

Some trials of fungicides and similar materials have been arranged on mushroom farms where diseases or competitors were prevalent. In the trials on " Bacterial Pit," M.R.A. staff applied the treatments and assessed the results, but in other cases the growers did one or both. The limitations of this procedure are recognised, but in the existing circumstances it is probably better than doing nothing, and when successful is welcomed by the growers.

Experiments with " Bacterial Pit "

During this year four experiments have been carried out by kind permission of Messrs. Noble Mushrooms Ltd., on beds in their houses which had been fairly severely affected by " Bacterial Pit."

In each case the experimental plot was 10 sq. ft. of bed. The first experiment was a rough trial of several substances which for various reasons might counter bacterial attack. Each treatment was applied to one bed, with two controls sprayed with water.

The best results were obtained on the two beds nearest to the door. This was probably due to their position rather than to the sprays used, water and 0·01% Rose bengal. It supports the view that inadequate ventilation is a major factor in causing this trouble.

In later experiments two or three plots received each treatment, with precautions against positional effects.

In three of the four experiments Alpha-naphthol appeared to reduce pitting slightly, but in no case was the effect great enough to be convincing. The same applied to TMTD in two out of three experiments. Further tests will be made with these and other substances as opportunities occur.

Fungicide tests

Following reports from America there has been considerable interest in one of the new fungicides, zinc ethylene-bis-dithiocarbamate, used in the preparations Parzate and Dithane Z.78. We were offered a supply of this material and also of tetramethylthiuram disulphide (TMTD) another new fungicide with rather similar properties.

One or both of these fungicides was sent to various mushroom growers who were having difficulty in controlling *Verticillium*, *Mycogone* and *Sporendonema* (Red Geotrichum).

Sometimes, but not always, areas of bed were left untreated for comparison. All results obtained in this way need further examination under controlled experimental conditions, but in some cases they have been striking enough to justify any time spent in this way. Until that has been done and more is known about the behaviour of the fungicides in question and about the occurrence of *Sporendonema* in particular, it would not be safe to make any general recommendations.

It is quite certain that the occurrence and severity of attack by some of these fungi depend on atmospheric conditions in the house, and it is highly probable that the effect of the fungicides is also affected. Complete uniformity of results between farms is therefore not to be expected. Both fungicides were usually applied as 0·1% sprays, occasionally stronger, at 1 gallon on 50-100 sq. ft. of bed before fruiting or between flushes.

Trials on *Mycogone perniciosa* with Dithane Z.78.

On all farms there were regular losses due to *Mycogone* before the trials started. On two farms attacks of *Mycogone* practically ceased after treatment, on three they were much reduced, and on one there was no noticeable difference.

Trials on *Verticillium* spp. with Dithane Z.78.

On one farm losses due to *Verticillium* practically ceased to appear but on two others it persisted in spite of treatment with Dithane.

Sporendonema (**Red Geotrichum**)

The status of this fungus on the mushroom bed is uncertain. Some growers consider it practically harmless, others have had very large areas of bed completely overrun with it. Such beds sometimes produced very small mushrooms, sometimes none at all.

In two cases where production had fallen, with heavy growth of *Sporendonema*, disappearance of *Sporendonema* after treatment was followed by a better flush of mushrooms.

There was some variation in the reported effect of both fungicides on subsequent flushes, which were sometimes delayed.

On two farms the effect of Dithane Z.78 in suppressing *Sporendonema*, and on one farm that of TMTD was striking.

Thus there is circumstantial evidence to suggest that *Sporendonema* may injure mushroom production, that its growth may be suppressed by Dithane Z.78 or TMTD, and that this may be followed by resumption of fruiting.

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